CLINICAL SERVICE AUDIT

Visceral adipose tissue quantification by CT in cardiac imaging patients with a raised waist-to-height ratio

Does CT-derived visceral adipose tissue index (VATI) provide metabolic risk information that cannot be obtained from waist-to-height ratio or BMI alone?

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Summary

This audit reviewed **123 evaluable CT visceral adipose tissue (VAT) studies** in cardiac imaging patients, the large majority meeting the local referral criterion of a waist-to-height ratio (WtHt) above 0.5. The aim was to test whether the visceral adipose tissue index (VATI) derived from the scan adds metabolic stratification beyond anthropometry. It does: within any narrow band of WtHt or BMI, measured VATI spanned the full width of the risk scale. Taken together, WtHt, BMI and sex explained only **43% of the variance in VATI** (residual SD 15.7 cm²/m² against a total of 20.6), so more than half of the between-patient variation could not be predicted from body shape. One in three normal-weight patients (BMI < 25) carried a high or very high visceral burden. Risk bands were assigned using sex- and ethnicity-specific VATI thresholds (Caucasian elevated-risk cut-points ≥ 38.7 cm²/m² men, ≥ 24.9 cm²/m² women).[1] These findings support continuing to offer VAT CT to this population and using the measured VATI — not anthropometry — to guide management.

1. Background and rationale

Visceral adipose tissue is metabolically active fat surrounding the abdominal viscera and is more closely linked to insulin resistance, type 2 diabetes, heart failure with preserved ejection fraction, atrial fibrillation and dementia than total body fat. BMI and waist-to-height ratio are convenient anthropometric surrogates of central adiposity, but neither distinguishes subcutaneous from visceral fat. A patient may be lean by BMI yet carry a high visceral burden (the “thin-outside-fat-inside” phenotype), or appear large yet store fat predominantly subcutaneously.

In this service, cardiac imaging patients are offered a thin-slice VAT acquisition at the level of L3 where the waist-to-height ratio exceeds 0.5. The visceral fat area is indexed to height squared to give the VATI (cm²/m²) and classified into sex- and ethnicity-specific metabolic risk bands. This audit examines whether that measured index adds information over the anthropometry available at referral.

2. Aim and audit standard

Audit standard: In cardiac imaging patients selected by a raised waist-to-height ratio, CT-derived VATI should stratify metabolic risk across a clinically meaningful range that is not predictable from WtHt or BMI alone, thereby providing additional information on which clinicians can base management.

Measurable objectives:

[1] Caucasian elevated-risk thresholds from Baggerman et al. (2022): men ≥ 38.7, women ≥ 24.9 cm²/m²; low-risk targets ≤ 35–38 (men) / ≤ 22–25 (women). Sex- and ethnicity-specific bands per the service reference-range document.

- Describe the body-composition and visceral fat profile of the cohort, de-identified and reported as ranges.
- Quantify the relationship between anthropometry (WtHt, BMI) and measured VATI.
- Determine the spread of VATI within narrow bands of WtHt and of BMI.
- Quantify the proportion of VATI variance left unexplained by anthropometry.
- Describe the behaviour of the WtHt > 0.5 referral gate against the measured result.

3. Methods

3.1 Design and data source

Retrospective service evaluation of consecutive VAT CT studies, conducted by Virtual Cath Lab Surrey (VCL-Surrey) Ltd. The studies were performed on patients referred to the host imaging site (Surrey Cardiovascular Clinic) and recorded in the service's structured reporting database. A single de-identified extract dated 1 June 2026 was analysed. No patient identifiers were used and only aggregate values are reported.

3.2 Inclusion and exclusions

The extract contained 126 records from 120 unique patients (six patients had a repeat or duplicate record). Three records with a missing or zero visceral fat measurement were excluded, leaving **123 evaluable studies**. Repeat records were retained as separate studies for descriptive analysis. A recorded age of ~56 years appeared as a data-entry default in 24 records and these were excluded from the age summary only.

3.3 Measurements and definitions

- **Waist-to-height ratio (WtHt):** measured waist circumference (cm) divided by height (cm). Referral threshold 0.5.
- **VAT area:** visceral fat cross-sectional area on the CT slice at L3 (cm^2).
- **VATI:** VAT area indexed to height squared (cm^2/m^2).
- **Metabolic risk band:** Standard / High / Very high, applied using sex- and ethnicity-specific VATI thresholds (see box).
- Full acquisition, slice-localisation, segmentation and bowel-artefact correction methods are specified in the service's methods reference (ref 11).

3.4 Statistical methods

Continuous variables are summarised as median, interquartile range (IQR) and range. Pearson correlations are reported with 95% confidence intervals (Fisher z). The shared dependence of WtHt and VATI on height was examined by also correlating the raw measures (waist vs VAT area) and by partial correlation controlling for height. Variance in VATI explained by anthropometry was assessed by ordinary least-squares regression (R^2). For the referral-gate analysis, a positive scan was defined as the reported High or Very high band. Analyses used Python (pandas, scipy, numpy).

> **Threshold basis (VATI metabolic risk bands)**
>
> VATI is normalised VAT area (VAT area ÷ height^2) measured on CT at L3. Risk bands are interpreted against sex- and ethnicity-specific thresholds, because visceral fat distribution and metabolic sensitivity differ by ancestry. For **Caucasian adults**, elevated metabolic risk begins at **VATI ≥ 38.7**

cm^2/m^2 (men) and ≥ 24.9 cm^2/m^2 (women), with low-risk targets of ≤ 35–38 (men) and ≤ 22–25 (women) and a "very high" band at ≥ 52 (men) / ≥ 60 (women). These derive from Baggerman et al. (2022), in 416 healthy Caucasian adults, supported by Shen (2004), Katzmarzyk (2013), Kong (2022) and the Bennett (2024) systematic review.

Because this cohort is almost entirely of Caucasian background, the Caucasian thresholds above were applied throughout; the male/female elevated-risk lines drawn in Figures 1 and 2 are these Baggerman cut-points. East Asian, South Asian, Middle Eastern and African-descent populations reach equivalent risk at lower VATI, and the service applies correspondingly adjusted thresholds where relevant. The numeric cut-points are taken from the primary peer-reviewed literature (principally Baggerman 2022, ref 1); the service reference-range document (ref 6) is the secondary synthesis that operationalises them for routine reporting.

3.5 Radiation dose of the added acquisition

Radiographer dose-audit fields — volume CT dose index (CTDIvol), dose–length product (DLP) and scan range — were recorded for the thin-slice VAT acquisition in a consecutive subset of studies. Because the VAT slice was usually added to a cardiac CT, the dose attributable to the VAT acquisition alone was isolated from any concurrent scan and analysed separately. Effective dose was estimated from the VAT-specific DLP using the standard abdominal conversion coefficient of 0.015 $mSv \cdot mGy^{-1} \cdot cm^{-1}$ (ICRP 103 / European Guidelines on Quality Criteria for CT). Dose data were available for 40 acquisitions after removal of one duplicate record; one further record was excluded because its log had captured the total exposure of a concurrent CTCA rather than the VAT slice alone, leaving 39 acquisitions with a clean VAT-only dose. Values are summarised as median (IQR) and range, with published reference doses for context.

4. Results

4.1 Cohort characteristics

The cohort was predominantly male (90 of 123, 73%) and middle-aged to elderly. Referrals came overwhelmingly from a single consultant cardiologist, and studies were performed by two operators. Table 1 summarises body composition and visceral fat, whole cohort and by sex.

Measure (units)	All (n = 123)	Male (n = 90)	Female (n = 33)
Age (years)[1]	65 (52–69); 38–97	—	—
BMI (kg/m^2)	27.1 (25.1–28.9); 18.0–43.4	27.4 (25.3–29.3); 23.5–43.4	25.9 (24.4–28.4); 18.0–43.1
Waist (cm)	100 (92–107); 70–142	102 (96–110); 72–142	86 (80–98); 70–126
Height (cm)	175 (169–180); 150–197	—	—
Weight (kg)	83 (74–92); 52–150	—	—
WtHt ratio	0.57 (0.52–0.61); 0.41–0.78	0.57 (0.54–0.61); 0.41–0.78	0.52 (0.50–0.60); 0.42–0.71
VAT area (cm^2)	129 (84–179); 15–297	146 (114–188); 30–297	81 (60–112); 15–183
VATI (cm^2/m^2)	40.9 (28.3–57.8); 5.2–102.8	45.0 (34.4–63.5); 9.9–102.8	29.3 (22.7–39.4); 5.2–59.4

Table 1. *Values are median (IQR); range. [1] Age on 69 records after excluding 24 default-coded entries.*

4.2 Distribution of metabolic risk

Across the cohort, **61% (75 of 123) fell into the High or Very high bands**. No woman in this sample reached the Very high band, which was the single largest group among men.

Risk band	All	Male	Female
Standard	42 (34%)	28	14
High metabolic risk	43 (35%)	25	18
Very high metabolic risk	37 (30%)	37	0
Total	≈123	90	33

Table 2. *Counts of evaluable studies by VATI metabolic risk band.*

4.3 Relationship between anthropometry and VATI

WtHt was positively but only moderately correlated with VATI, and the relationship differed depending on whether height-indexed or raw measures were used. Because both WtHt and VATI contain height in their denominator (height^1 and height^2), part of the height-indexed correlation is a shared-denominator artefact; the raw and height-controlled estimates are therefore more faithful (Table 3).

Relationship	n	Male r (95% CI)	Female r (95% CI)
WtHt vs VATI (both height-indexed)	90 / 33	0.56 (0.40–0.69)	0.61 (0.34–0.79)
Waist (cm) vs VAT area (cm²) — raw	90 / 33	0.47 (0.30–0.62)	0.66 (0.41–0.82)
WtHt vs VATI, controlling for height	90 / 33	0.54	0.62

Table 3. *Pearson correlations with 95% CI; all $p < 0.001$. At best anthropometry explains roughly half the variance in visceral fat ($r^2 \approx 0.5$); at the lower bound, nearer 15%.*

4.4 Spread of VATI within narrow anthropometric bands

This is the central finding. Grouping patients into narrow bands of WtHt — or of BMI — the measured VATI still ranges across essentially the whole scale, with all three risk bands represented within every band. Two patients with the same ratio, or the same BMI, can sit at opposite ends of the risk spectrum.

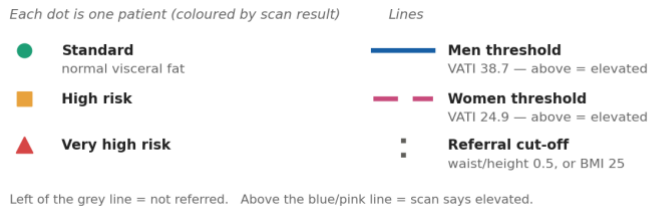
WtHt band	n	VATI range (median)	Risk bands present
0.50 – 0.55	30	12 – 50 (26)	Standard → Very high
0.55 – 0.60	37	20 – 88 (43)	Standard → Very high
0.60 – 0.65	33	14 – 103 (57)	Standard → Very high

Table 4. *VATI (cm²/m²) within narrow waist-to-height bands.*

BMI band (kg/m²)	n	VATI range (median)	Risk bands present
23 – 25	28	9 – 68 (26)	Standard → Very high
25 – 27	29	10 – 69 (38)	Standard → Very high
27 – 30	41	14 – 102 (54)	Standard → Very high
30 – 35	16	20 – 103 (48)	Standard → Very high

Table 5. *VATI (cm²/m²) within narrow BMI bands.*

Figures 1 and 2 show the same data split by sex, with each point coloured by its reported metabolic risk band. Each panel carries that sex's single elevated-risk VATI threshold (men 38.7, women 24.9; blue line) and the screening cut-point (WtHt 0.5, or BMI 25; dotted). At every position along the x-axis the points span almost the full height of the panel, and standard, high and very-high cases are interleaved throughout — visual confirmation that neither anthropometric metric places a patient on the visceral fat scale. No woman in this cohort reached the very-high band.



Key. *How to read Figures 1 and 2. Applies to both plots.*

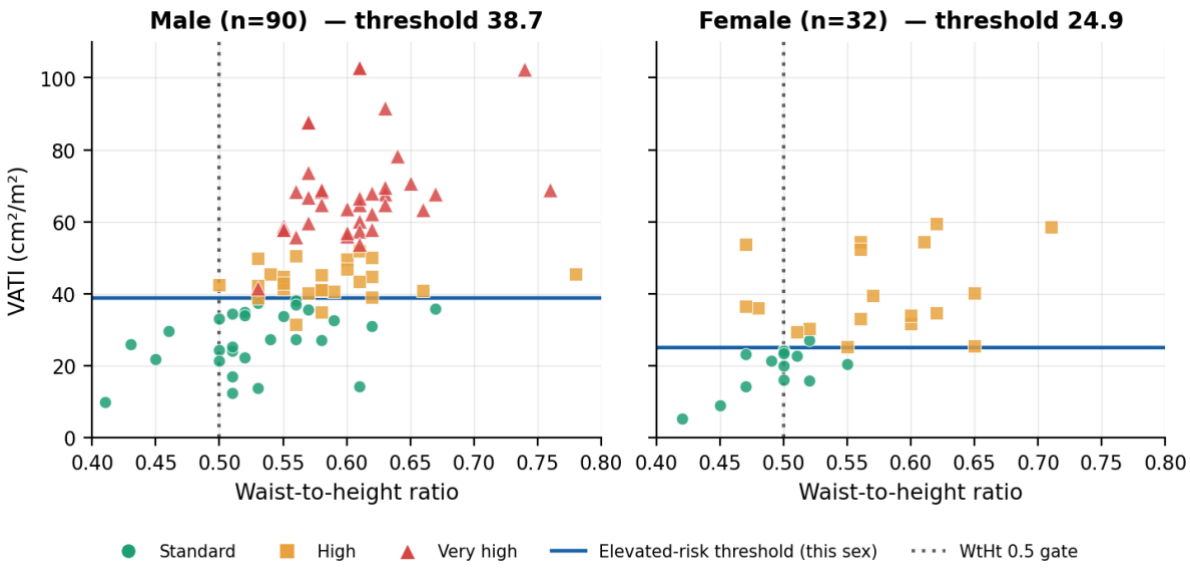


Figure 1. *Waist-to-height ratio vs VATI, by sex, coloured by reported risk band. WtHt is a sensitive gate (few elevated-VAT patients lie left of the 0.5 line) but a weak predictor of the result — all bands occur at every ratio. The female sample is small (n = 32) with no very-high cases.*

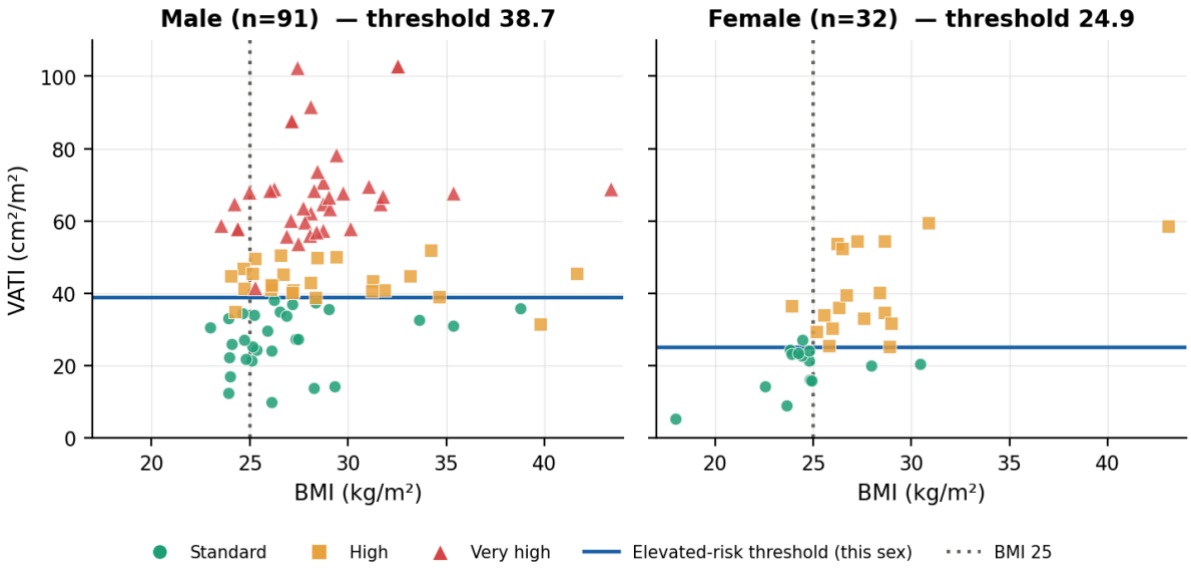


Figure 2. *BMI vs VATI, by sex, coloured by reported risk band. BMI performs worse (it explains only 11% of VATI variance): elevated-risk patients appear well below BMI 25, and standard-risk patients among the obese.*

4.5 Discordance between body shape and visceral fat

Consistent with the band analysis, body-shape category frequently disagreed with the measured burden:

- **10 of 30 normal-weight patients (33%, BMI < 25)** had a High or Very high visceral burden — they would have been falsely reassured by BMI.
- **4 of 23 obese patients (17%, BMI ≥ 30)** had only a Standard burden — BMI overstated their visceral risk.

4.6 Variance in VATI explained by anthropometry

Formal regression confirms the band analysis: anthropometry leaves the majority of visceral fat variation unaccounted for, with a residual scatter large relative to the width of the risk bands themselves.

Predictors of VATI	Variance explained (R^2)
BMI alone	0.11
WtHt alone	0.36
WtHt + BMI	0.38
WtHt + BMI + sex	0.43

Table 6. *Even the fullest anthropometric model explains under half the variance in VATI; residual SD 15.7 vs total SD 20.6 cm^2/m^2.*

4.7 Behaviour of the WtHt > 0.5 referral gate

Treating WtHt > 0.5 as the referral trigger and the reported High/Very high band as a positive scan, the gate behaved as a sensitive but non-specific screen (Table 7). It almost never missed a patient with elevated visceral fat — particularly in men, where it operated as a near-complete catch — but a substantial proportion of those referred returned a standard result. This is the expected behaviour of a screening rule and confirms it selects who to image rather than predicting the result.

Group	Sensitivity	Specificity	n
Male	100%	17%	91
Female	83%	36%	32
All	96%	23%	123

Table 7. *Performance of WtHt > 0.5 against the reported metabolic risk band (High or Very high). The three female false-negatives were patients below the 0.5 gate with an elevated band.*

4.8 Radiation dose of the added VAT acquisition

The thin-slice VAT acquisition was performed at a fixed CTDIvol of 19.1 mGy. The incremental dose–length product was low and tightly clustered (median 8.8 mGy·cm, IQR 8.2–10.7), giving a median additional effective dose of 0.13 mSv (IQR 0.12–0.16; range 0.09–0.19; Table 8). In context, the added acquisition delivers roughly the radiation of 18 days of natural background exposure in the United Kingdom, about seven chest radiographs, or one-third of a screening mammogram, and approximately one-eighth of the dose of a coronary artery calcium score (Figure 3). The visceral-fat measurement therefore carries a negligible radiation penalty relative to the metabolic information it provides.

Dose parameter (units)	Median (IQR); range
CTDIvol (mGy)	19.1 (fixed protocol)
Incremental DLP (mGy·cm)	8.8 (8.2–10.7); 5.7–12.9
Additional effective dose (mSv)	0.13 (0.12–0.16); 0.09–0.19

Table 8. *Radiation dose of the added thin-slice VAT acquisition (39 acquisitions with a clean VAT-only dose), reported separately from any concurrent cardiac CT. Effective dose derived from DLP using $k = 0.015\ mSv \cdot mGy^{-1} \cdot cm^{-1}$.*

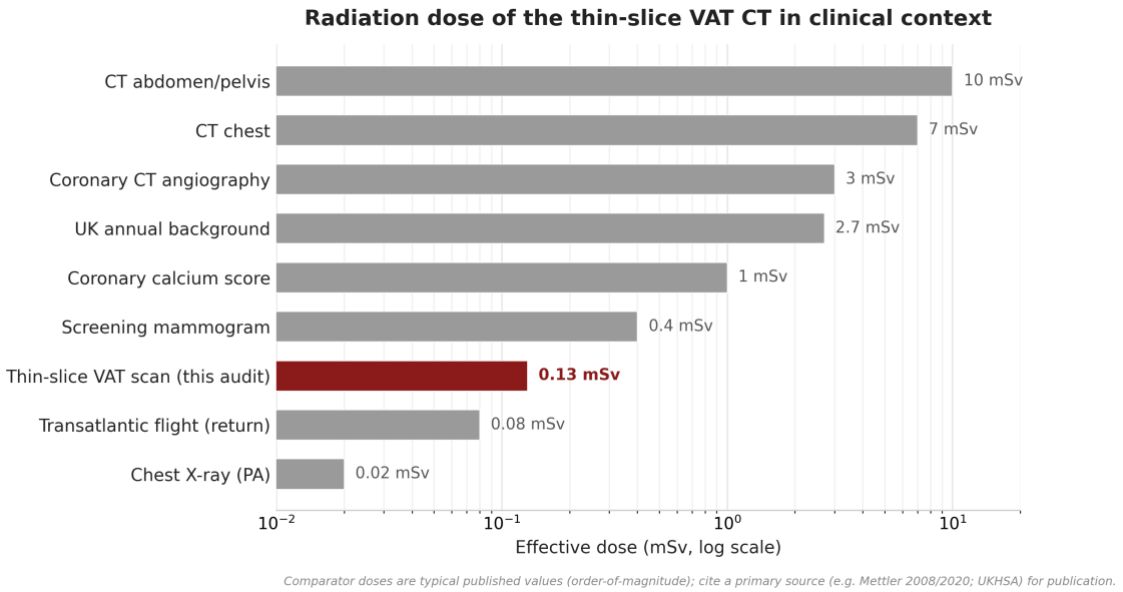


Figure 3. *Effective dose of the added VAT acquisition in clinical context (log scale). The VAT acquisition (highlighted) sits between a chest radiograph and a screening mammogram, well below the cardiac CT it accompanies. Comparator values are typical published effective doses, order-of-magnitude (Mettler 2008, ref 10).*

5. Discussion

The audit standard was met. In a population already enriched for central adiposity by the WtHt > 0.5 rule, CT-measured VATI was distributed across the full metabolic risk range and could not be reconstructed from WtHt or BMI: within any narrow anthropometric band all three risk categories were present, and a comprehensive anthropometric model explained only 43% of VATI variance. The one-in-three normal-weight patients with a high visceral burden are precisely the group conventional screening misses; the obese patients with only standard visceral fat are those in whom body shape overstates risk.

For clinicians, the implication is that the scan result, not the referral anthropometry, should drive management — lifestyle intensity, consideration of GLP-1 or SGLT2 therapy, glycaemic surveillance and cardiovascular risk discussion. Waist-to-height ratio remains a reasonable, low-cost gate for deciding whom to image (high sensitivity) but is a poor predictor of the quantitative result.

Applying the published sex- and ethnicity-specific VATI thresholds is important: equivalent metabolic risk arises at lower VATI in East and South Asian populations than in Caucasians, so a single set of cut-points would misclassify a multi-ethnic cohort. In this predominantly Caucasian sample the Baggerman cut-points are appropriate and reproduced the reported bands closely.

The dose audit supports this benefit–risk balance. The visceral-fat acquisition (120 kVp, 200 mA, 1 mm slice; CTDIvol ≈ 19.1 mGy) added a median of only 0.13 mSv — comparable to a few weeks of natural background radiation, a fraction of the cardiac CT it usually accompanies, and below a screening mammogram — so the additional metabolic stratification is obtained at a radiation cost that is, for practical purposes, negligible. Because only a single thin slice is taken, the added dose was essentially independent of body size (dose–length product correlated with neither BMI nor waist; r = 0.25 and 0.16, both non-significant), tube output being increased only for the largest patient. This is relevant both to justification of the added acquisition under IR(ME)R and to how the exposure is described to patients at consent.

A measurement-reproducibility issue was identified during the audit and has since been corrected. The measurement level itself is unchanged — 3 cm above the lower margin of L3, the level shown to best

reflect change in total visceral fat volume (Noumura et al., 2017, ref 8) and on which the service's VATI reference ranges are based. Consistent with this, the radiographer dose log recorded 44 of 46 acquisitions at the prescribed level (3 cm above the lower margin of L3), with 2 logged one level lower before standardisation. On reviewing follow-up studies, however, the slice was found to vary between scans because radiographers differed in how they located that level. From June 2026 only the method of locating it has been standardised (SOP Addendum 1): the L3 inferior endplate is identified on the mid-sagittal scout and the slice taken 3 cm cranially along the table axis, with a fixed reconstruction interval permitting a tool-free slice-count check and the previous prescription replicated for follow-up scans. This removes operator-dependent variation while keeping the validated level, preserving comparability with prior scans and with the published reference data on which the risk bands are based.

6. Limitations

- Single-centre service evaluation; the cohort was predominantly male and Caucasian, limiting generalisability.
- The female sample was small (n = 33) with no Very high VATI cases, so female estimates have wide confidence intervals.
- Six patients contributed repeat or duplicate records treated as separate studies in descriptive analyses.
- Risk bands depend on the chosen VATI thresholds; although these are evidence-based, non-Caucasian thresholds are themselves extrapolated in places (see box).
- Cross-sectional audit of measurement information content; it does not assess clinical outcomes or the effect of management change.
- Until June 2026 the slice at the prescribed level (3 cm above the lower margin of L3) was located by operator-dependent judgement, introducing some variability between sequential scans; the level is unchanged but the method of locating it has since been standardised, so the comparability of the earlier repeat studies in this extract is limited.
- A single-slice area is a validated cross-sectional surrogate for total visceral fat volume but tracks change in total VAT volume less precisely (Shen et al., 2012, ref 9); serial VATI should be interpreted as a trend signal rather than an exact volumetric change.

7. Conclusions and recommendations

CT-derived VATI provides metabolic risk stratification that cannot be obtained from waist-to-height ratio or BMI in this cardiac imaging population, supporting continued VAT acquisition for patients meeting the WtHt > 0.5 criterion and use of the measured index to guide management.

- Continue to use WtHt > 0.5 as the referral gate, recognising it as a sensitive selector rather than a predictor of the result.
- Base management on the measured VATI and its sex- and ethnicity-specific risk band, not on anthropometry.
- Improve data quality at entry: eliminate the default age value, prevent zero/blank VAT entries, and de-duplicate repeat studies.
- Prospectively broaden referral sources and female recruitment, and link VATI bands to recorded management and outcomes in the next cycle.

- Continue to acquire at the established level — 3 cm above the lower margin of L3 — locating it by the standardised method in SOP Addendum 1 (L3 inferior endplate identified on the mid-sagittal scout, slice taken 3 cm cranially, with a slice-count check), implemented 18 June 2026, to ensure reproducible sequential measurements.
- Retain the thin-slice VAT acquisition: at a median 0.13 mSv it adds negligible radiation for clinically meaningful metabolic information, and record CTDIvol/DLP routinely to sustain the dose audit.

Declarations

Authorship and conflict of interest: this audit was conducted and written by Dr E Leatham and Dr M Hickman, who are both directors of Virtual Cath Lab Surrey (VCL-Surrey) Ltd, a commercial provider of CT imaging services. Its conclusions support the continued provision of CT-based visceral-fat assessment — a service from which the authors' company may derive commercial benefit — and readers should weigh the findings with this interest in mind. To limit that influence, the VATI thresholds applied are drawn from the published peer-reviewed literature (principally Baggerman et al., 2022) rather than any in-house standard; all data are reported de-identified and in aggregate; and the reference-range document cited (reference 6), authored by Dr Leatham, is openly archived. No external funding was received.

References

1. Baggerman MR, et al. Computed tomography reference values for visceral obesity and increased metabolic risk in a Caucasian cohort. Clin Nutr ESPEN. 2022;48:408–13. https://doi.org/10.1016/j.clnesp.2022.01.009

2. Shen W, et al. Visceral adipose tissue: relations between single-slice areas and total volume. Am J Clin Nutr. 2004;80(2):271–8. https://doi.org/10.1093/ajcn/80.2.271

3. Katzmarzyk PT, et al. Clinical utility of visceral adipose tissue for identification of cardiometabolic risk in white and African American adults. Am J Clin Nutr. 2013;97(3):480–6. https://doi.org/10.3945/ajcn.112.047787

4. Kong M, et al. Assessing visceral obesity and abdominal adipose tissue distribution on CT: a large multicentre cross-sectional study. Front Nutr. 2022;9:871697. https://doi.org/10.3389/fnut.2022.871697

5. Bennett JP, et al. Evaluation of visceral adipose tissue thresholds for elevated metabolic syndrome risk across diverse populations: a systematic review. Obes Rev. 2024;25(9):e13767. https://doi.org/10.1111/obr.13767

6. Leatham E. Proposed reference ranges on healthy visceral adipose tissue index (VATI) targets by ethnicity (CT at L3). Virtual Cath Lab Surrey (VCL-Surrey) Ltd; 2025. Available from: https://archive.org/details/proposed-reference-ranges-on-healthy-visceral-adipose-tissue-index-vati-targets-. Accessed 18 June 2026.

7. Irlbeck T, Massaro JM, Bamberg F, O'Donnell CJ, Hoffmann U, Fox CS. Association between single-slice measurements of visceral and abdominal subcutaneous adipose tissue with volumetric measurements: the Framingham Heart Study. Int J Obes (Lond). 2010;34(4):781–787. https://doi.org/10.1038/ijo.2009.279

8. Noumura Y, Kamishima T, Sutherland K, Nishimura H. Visceral adipose tissue area measurement at a single level: can it represent visceral adipose tissue volume? Br J Radiol. 2017;90(1077):20170253. https://doi.org/10.1259/bjr.20170253

9. Shen W, Chen J, Gantz M, Punyanitya M, Heymsfield SB, Gallagher D, et al. A single MRI slice does not accurately predict visceral and subcutaneous adipose tissue changes during weight loss. Obesity (Silver Spring). 2012;20(12):2458–2463. https://doi.org/10.1038/oby.2012.168

10. Mettler FA Jr, Huda W, Yoshizumi TT, Mahesh M. Effective doses in radiology and diagnostic nuclear medicine: a catalog. Radiology. 2008;248(1):254–263. https://doi.org/10.1148/radiol.2481071451

11. Leatham E, Hickman M. Measurement of visceral adipose tissue by low-dose CT at L3: acquisition, slice localisation, segmentation, bowel-artefact correction, and height/waist normalisation [methods reference]. Virtual Cath Lab Surrey (VCL-Surrey) Ltd; 2026. Available from: https://archive.org/details/vat-methods-reference-paper